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## ABSTRACT

For a successful enemy maneuver, their most important action is the ability to identify, locate and track the correct target. High-resolution imaging sensors such as the inverse synthetic aperture radar perform this action in the most effective way and are especially useful against low radar cross section targets. Once the correct target is acquired and identified, the decision to engage is made and the weapons are selected. *Counter-targeting* is the attempt to prevent (or degrade) the engage-and-launch-weapons decision by the enemy. This paper describes an all-digital image synthesizer technique capable of generating realistic false-target images for counter-targeting using modern digital radio frequency memory technology. The use in counter-lock on for coherent seekers in the terminal mode is also discussed. Examples of the output false target image capability are presented.

## I. PRECISION ENGAGEMENT

Force movement, maneuver, and sustainment over long distances are the characteristics of a successful enemy organization. This success comes in part from the use of precision engagement against U. S. and coalition operational targets to attempt a decisive outcome for their campaigns and major operations. Precision engagement for the enemy involves targeting and then allocating the selected targets to the most appropriate hard-kill weapon systems. The time from location and identification of a target to weapon arrival is important for success. That is, the speed at which the enemy can deliver the weapon to the correct target has great significance [1]. The precision engagement process is summarized in Figure 1. The process begins with locating, acquiring and identifying the target using a high-resolution imaging sensor such as *inverse synthetic aperture radar* (ISAR). The ISAR provides the target's range, bearing and positional data using high resolution images for display and recording.

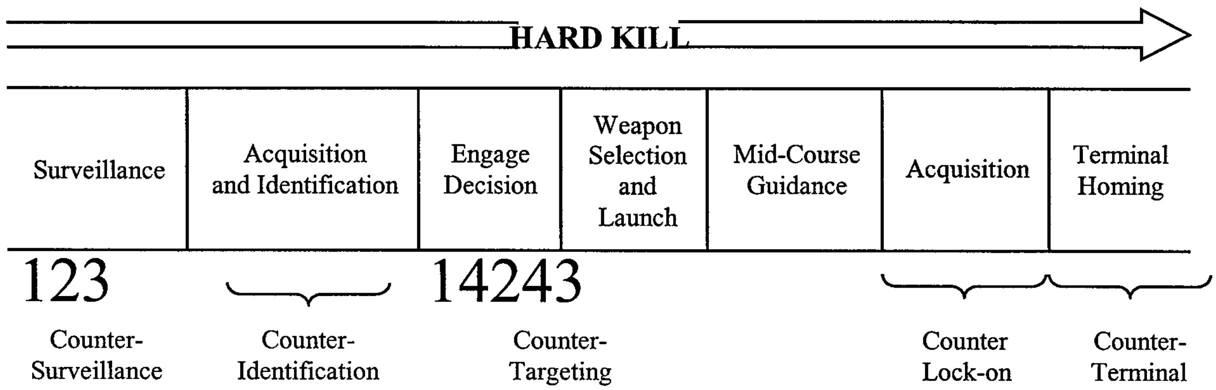


Figure 1. Precision engagement process for the terrorist.

For example, the Russian Sea Dragon maritime patrol radar employs an ISAR 2-D imaging mode to detect and classify surface and surfaced submarine targets within 150 km. Depending on the ISAR target identification, the decision to engage the target and launch the weapon is made and only the ability to quickly confuse this targeting process can prevent the weapon from being launched.

Actions taken to confuse or deceive the enemy's pre-launch weapons designation and targeting efforts are known as *counter targeting* techniques. Few key targets are stationary and deception is a major part of counter targeting. Counter targeting actions include the use of low radar cross section materials, stealth, and deception devices in order to disrupt the weapons targeting prior to valid lock-on, thus preventing the enemy from obtaining an accurate fire control solution. Unfortunately, these actions are largely ineffective against wideband imaging sensors such as the ISAR.

The terminal homing modes of future threat missiles are also expected to use wideband imaging seekers. The use of an ISAR seeker in the terminal phase of a missile attack allows decoy rejection and good aimpoint accuracy, resulting in a greater probability of kill. Actions to deceive or degrade missile acquisition and homing modes are known as *counter lock-on* and *counter terminal* techniques respectively. Currently, counter lock-on actions consist of electronic attack (jamming), distraction chaff and seduction chaff, as well as decoy repeaters. However, these actions are not always practical against high-resolution imaging seekers.

## II. IMAGING SENSOR TECHNOLOGY

ISAR is similar to spotlight synthetic aperture radar (SSAR) [2]. Instead of blip type recognition of a signal reflecting off a target, ISAR and SSAR collect and processes many signals to form a range, cross-range image of the target. They both use a pulse compression waveform to achieve a high range resolution. They differ however, in the way the cross-range resolution is obtained. For the SSAR the movement of the sensor is used to create a "synthetic" antenna aperture between the sensor and the target as shown in Figure 2(a). The circular (focused) SSAR *motion* through the angle $\psi$ provides the Doppler frequency shift between the various parts of the target and the sensor in order to obtain the cross-range samples. The ISAR movement is shown in Figure 2(b). Here the *target motion* (e.g., ship rocking on the sea) provides the Doppler frequency shift between the various parts of the target and the sensor unit. The ISAR is a useful sensor for maritime precision engagement since sensor platform movement about the target is not required. That is, stand-off imaging can be done from a great distance using only a single sensor-target aspect angle.

An example of an ISAR range, cross-range image of a ship is shown in Figure 3 [3]. Figure 3(a) shows the photo of the U. S. S. Crockett. The ISAR image of the U. S. S. Crockett is shown in Figure 3(b). These types of images can be used for classification and engage decisions. Note the two masts and the ship superstructure details are clearly evident in the ISAR image. With only a small amount of computer processing, these types of images can be used for target identification.

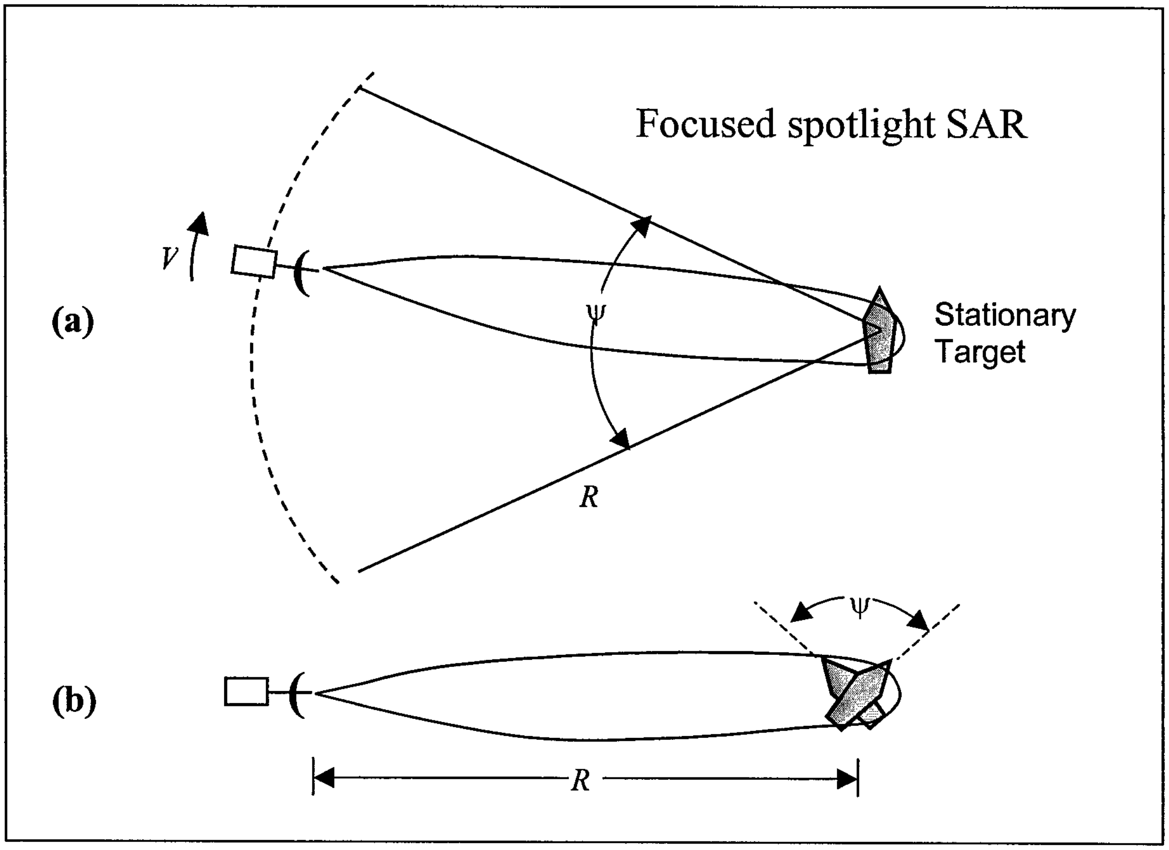


Figure 2: (a) Focused spotlight synthetic aperture radar (SSAR) mode and (b) Inverse synthetic aperture radar (ISAR) mode.

(a)

(b)

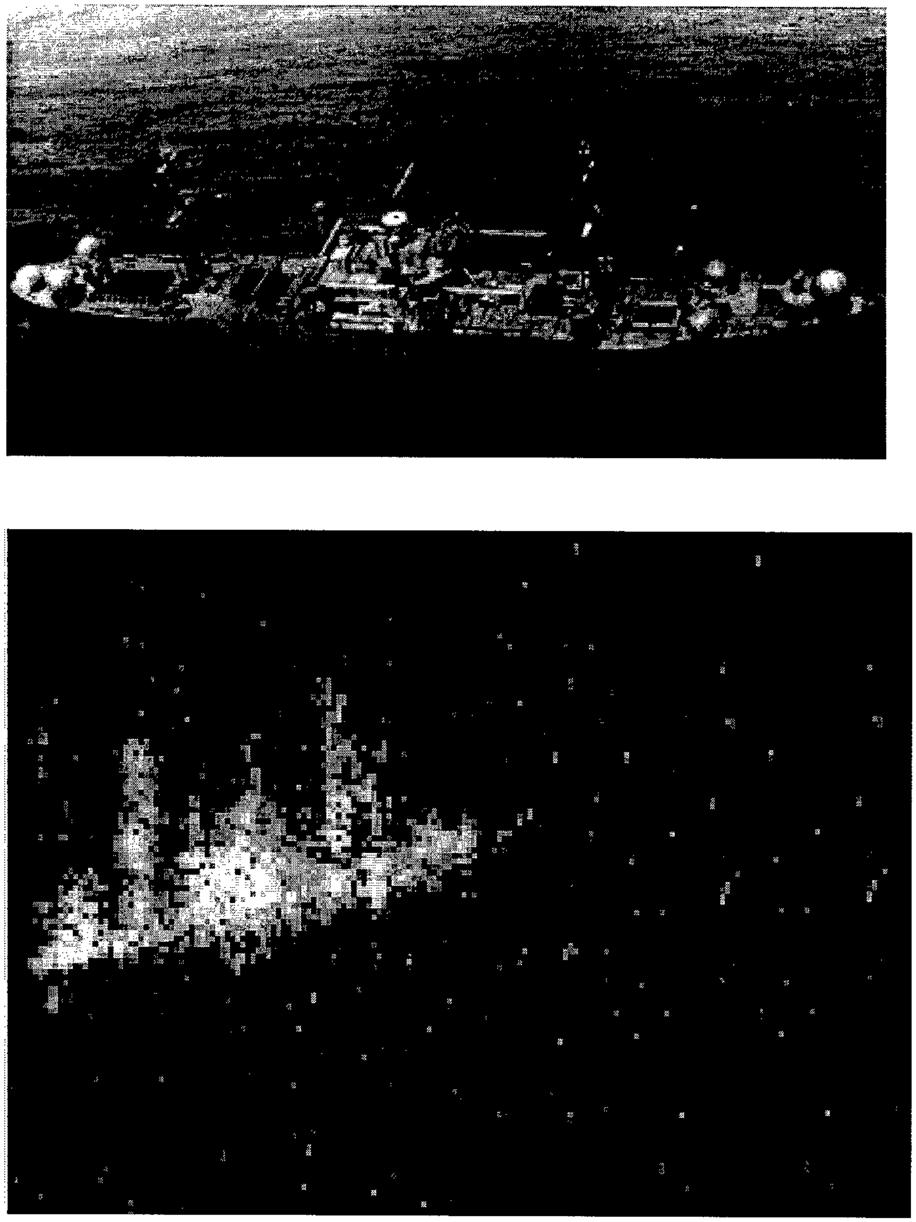

Figure 3: (a) the USS Crockett and (b) an AN/APS-137 ISAR image of the USS Crockett [3].

## III. FALSE-TARGET IMAGE SYNTHESIZER TECHNOLOGY

The need for coherent countering of ISAR imaging sensors remains a high priority for many electronic warfare systems. Methods of generating realistic false targets to counter wideband-imaging radars have historically used acoustic charge transport (ACT) analog tapped delay lines or fiber optic tapped delay lines. ACT devices however, are no longer commercially available and also have a limited bandwidth, making them impractical against wideband imaging radars.

Optical devices are bulky and costly to manufacture, especially for the long delay line lengths representative of large target delays. Furthermore, neither of these technologies can be rapidly reprogrammed to synthesize realistic (moving) false target images.

Advances in integrated circuit fabrication technology such as sub-micron complementary metal-oxide-semiconductor (CMOS) and Bipolar CMOS (BiCMOS) for Application Specific Integrated Circuits (ASICs) have greatly enhanced available speeds and gate densities in modern digital circuits. Speeds exceeding 1 GHz and densities reaching 25 million usable gates are currently available. These capabilities, along with reduced production costs, suggest that a programmable imaging architecture for generating realistic false target signatures can be realized using custom digital ASICs integrated with modern Digital RF Memory (DRFM) technology.

Recently, an all-digital image synthesizer capable of generating multiple false-target images has been developed. The false targets are generated from a series of intercepted ISAR chirp pulses to provide a novel counter targeting and counter lock-on capability. The digital image synthesizer can be also be deployed for Suppression of Enemy Air Defense and any operation that encounters interrogating imaging sensors. For example, a suppression aircraft (e.g., EA-6B) can create a large number of false aircraft images forcing the enemy's integrated air defense to come on line. The device can be deployed on aircraft, ships, unmanned air or surface vehicles to provide a superior imaging decoy and deception capability.

A block diagram of the false-target image synthesizer system is shown in Figure 4. The intercepted chirp pulses from the sensor are first down-converted in the receiver, sampled by an analog-to-digital converter (ADC) and stored in high-speed memory. The samples of each intercepted pulse are processed by the programmable target imaging ASIC to create the false targets using a series of complex range bin modulators. The digital output of the ASIC is converted to an analog signal using a digital-to-analog-converter (DAC) and up-converted to the carrier frequency for retransmission back to the sensor. As the sensor processes the returned pulses, a high-resolution image of a false target is created.

The image synthesizer performs the complex modulations to synthesize the temporal lengthening and amplitude modulation due to the many recessed and reflective surfaces of the desired false target and also generates a realistic Doppler profile for each surface. The ASIC contains a parallel array of $N_r$ identical digital modulators with one modulator for each false target range bin. That is, each modulator synthesizes the part of the overall false target image that lies within the range bin associated with that modulator. Each complex output pulse $I(m,n)$ is the superposition of $N_r$ copies of the intercepted pulse, each delayed with respect to one another by the delay within the modulator, scaled differently by the gains $2^{g(r,n)}$ (binary shift) and phase rotated by $\phi_{inc}(r,n)$ as [4]

$$I(m,n)=\sum_{r=0}^{N_r-1} 2^{g(r,n)} e^{j[\phi(m-r,n)+\phi_{inc}(r,n)]} \tag{1}$$

Here $m$ represents the sample number within the chirp pulse, $n$ is the pulse number index, $r$ represents the range bin modulator index and $\phi(m-r,n)$ is the phase of the sample number. The target extent is controlled by shutting down or opening up, the proper range bin modulators. The amplitude, and target motion (Doppler) are controlled by the gain and phase increment

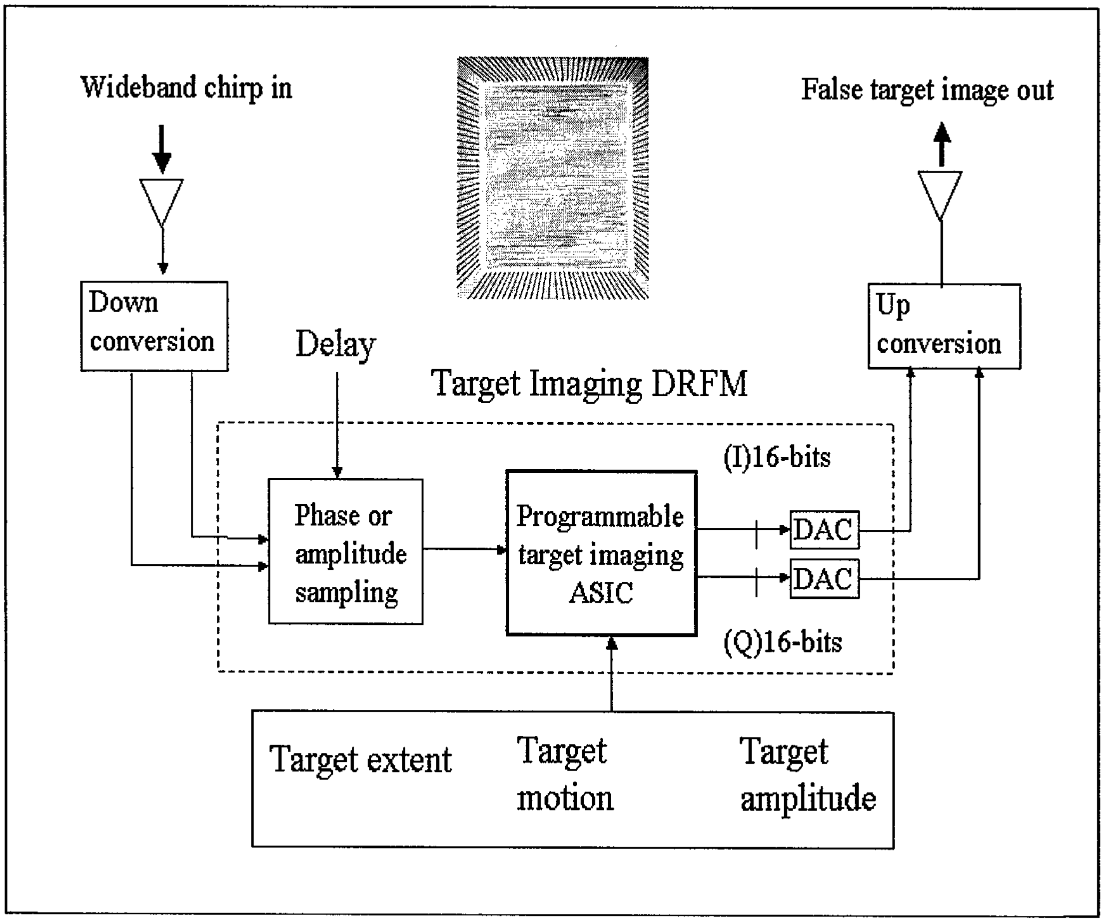


Figure 4: Block diagram of the false target image synthesizer.

coefficients applied to the ASIC. Also note that this capability can not be achieved using only digital RF memory technology since the number of complex modulations is extensive.

As an example, Figure 5(a) shows a range-Doppler matrix that can be used to create a false-target and shows the individual scatters and their corresponding Doppler frequency. Note the similarity to the ISAR image in Figure 3(b). The coefficients necessary to program the complex modulators in the ASIC can be derived for each range bin using these types of range-Doppler matrices. Figure 5(b) shows a MATLAB simulation of the image formed in an ISAR sensor after processing the image synthesizer return pulses. The range-Doppler description of the false-target ship with thirty-two range bins has a configuration that closely matches the ISAR image of the USS Crockett and demonstrates the feasibility of the architecture to generate false target images.

## IV. COUNTERING THE IMAGING SENSOR

To build a database of realistic false-target image coefficients, the Fast-Radar Target Signature (RTS) model within the CRUISE_Missiles engagement simulation at the Naval Research Laboratory (NRL Code 5750) is used. For example, the coefficients for an aircraft carrier as a false target within a sea multipath environment can be derived. The Fast-RTS model is rigorously derived from the RTS model (NRL Code 5314), which is a first principles physics-based radar cross section prediction code, and is the Naval Sea Systems Command (NAVSEA) standard for ship RF signature prediction. The resolution and RF frequency used to generate the coefficients are those of the threat ISAR. Note that this decoy capability however, is not limited to sea surface targets. The coefficients to generate images of aircraft, and building structures can easily be derived. One important note here is that in addition to the desired false target, the proper clutter profile (sea clutter, land clutter) has to also be included in deriving the coefficients in order that the target appears realistic.

The time-space position of the false target is easily controlled. The position in range can be controlled by delaying in time, the return (modulated) pulses from the image synthesizer. Since the pulse repetition frequency of imaging sensors can not change within a frame time, positioning the false target image at a range *closer to the sensor* can also be accomplished by returning the stored and modulated pulses earlier. To position the false target image in angle, the image synthesizer can be carried on an off-board decoy such as the NULKA. Other methods to position the false target in angle include coherently combining the image synthesizer with cross-eye jamming or other angle electronic attack.

## V. CONCLUDING REMARKS

The digital image synthesizer chip was developed by a student/faculty team at the U. S. Naval Postgraduate School's Center for Joint Services Electronic Warfare [5 – 15]. The 5.5 million-transistor chip has been fabricated to ensure operation at 700 MHz and includes 512 fully programmable range bin processors. The chip fabrication parameters include,

- 0.18 um CMOS 6 metal process (TSMC)
- 11.5 x 11.5 mm die size
- 5.5 million CMOS transistors
- 257-pin Pin Grid Array package

This new device will be capable of synthesizing multiple false target images against coherent emitters that perform range-Doppler processing. After testing and integration with the digital RF memory, the device will be available for theater operations (late FY05).

## Acknowledgements

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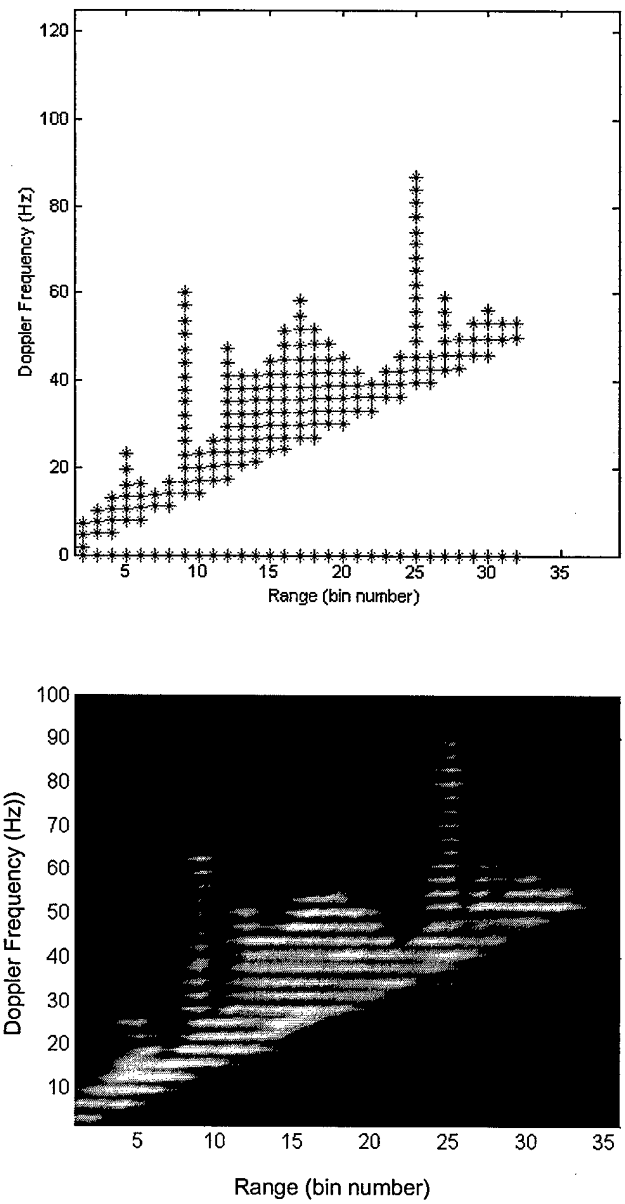


Figure 5: (a) False-target creation matrix and (b) false-target at the output of ISAR compression process.